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GEOPHYSICS.—*On the flow of heat from a rock stratum in which heat is being generated.*[1] C. E. VAN ORSTRAND, U. S. Geological Survey.

Numerous investigators have made the assumption that heat is developed in certain formations, particularly in oil sands. A possible test of this hypothesis consists in comparing the theoretical depth-temperature curves obtained on the basis of a generation of heat in a single stratum with the observed depth-temperature curves. Stated geologically, the problem is this:

Let it be assumed for convenience that the earth is a cooling globe and that the strata are parallel to the horizontal surface of the ground. After the lapse of several hundreds of millions of years t_1, heat is supposed to be developed in one of the thin horizontal layers at a constant or variable rate for a very long interval of time t. It is required to determine the nature of the depth-temperature curves after the earth has cooled for $t_1 + t$ years, during which time heat was developed in one of the strata for the last t years of the period $t_1 + t$.

Mathematically, we have to determine the solution for the semi-infinite solid subject to the conditions:—

$$\begin{array}{llllll} v = f_1(x) & \text{when} & t_1 = 0 & \text{and} & x \geqq 0 & \\ v = f(x) & " & t_1 = t_1 & " & x \geqq 0 & \\ v = f(x) & " & t = 0 & " & x \geqq 0 & \\ v = 0 & " & t_1 \geqq 0 & " & x = 0 & (1) \\ v = 0 & " & t \geqq 0 & " & x = 0 & \\ v = \phi(t) & " & t \geqq 0 & " & x = x' & \end{array}$$

These equations and inequalities state that a permanent heat source, $v = \phi(t)$, is maintained at a distance x' from the face of the slab; that the surface of the slab, $x = 0$, is maintained at constant tempera-

[1] Published by permission of the Director, U. S. Geological Survey. Received August 12, 1932.

ture, $v = 0$, for all values of the time; and that the temperature distribution in the slab at the time, $t = 0$, when heat is first generated in the slab is, $v = f(x)$. This relation results from the cooling of the slab from the initial temperature distribution, $v = f_1(x)$, through the time interval t_1. That is, in the course of t_1 years, the function, $v = f_1(x)$, becomes, $v = f(x)$, which is now the temperature distribution in the slab at the time $t = 0$.

In addition to satisfying conditions (1), it is necessary to satisfy the fundamental equation of heat conduction, namely,

$$\frac{\partial v}{\partial t} = \kappa \frac{\partial^2 v}{\partial x^2} \tag{2}$$

in which κ is the coefficient of diffusivity of the rocks above and below the plane, $x = x'$, on which the heat is supposed to be concentrated. To be strictly accurate, the thickness of the heat-generating bed should be taken into account, but inasmuch as the distances traversed by the heat are very great in comparison with the thickness of the bed, it will suffice for a first approximation to assume that all of the heat generated in the bed is concentrated on the plane, $x = x'$, from which it flows in both directions.

Various methods of procedure are possible. Let us adopt the method of heat sources in which sources of negative intensity (sinks) in the negative portion of the plane correspond to equal positive sources in the positive portion of the plane. The solution consists in performing the summations for all of the sources and sinks from $x = +\infty$ to $x = -\infty$.

That portion of the solution in which the instantaneous heat sources and sinks represent the arbitrary temperature distribution, $v = f_1(x)$, when the earth first began to cool is given by the equation[2]

$$v_1 = \frac{1}{2\sqrt{\pi \kappa t_1}} \int_0^\infty f_1(\lambda) \left[e^{-\frac{(\lambda - x)^2}{4\kappa t}} - e^{-\frac{(\lambda + x)^2}{4\kappa t}} \right] d\lambda \tag{3}$$

Now let us assume that the earth cooled from an initial temperature, v_o, then $v_o = f_1(x)$, and (3) becomes

$$v_1 = f(x) = v_0 \cdot \frac{2}{\sqrt{\pi}} \int_0^{\frac{x}{2\sqrt{\kappa t_1}}} e^{-\beta^2} d\beta \tag{4}$$

To this equation, calculated for the time interval $t_1 + t$, we must add the rise in temperature due to the single heat source at $x = x'$.

[2] L. R. INGERSOLL and O. J. ZOBEL. *An introduction to the theory of heat conduction.* (Ginn and Co.) pp. 76–77.

In order to maintain a constant zero temperature at the surface of the earth, we must add an equal sink at $x = -x'$. Hence we have for the instantaneous source and sink

$$v = \frac{v_q}{2\sqrt{\pi\kappa t}}\left(e^{-\frac{(x'-x)^2}{4\kappa t}} - e^{-\frac{(x'+x)^2}{4\kappa t}}\right) \tag{5}$$

in which $\phi(t)$ has been replaced by v_q, where

$$v_q = q/\rho c \tag{6}$$

is the rise in temperature in 1 cc of rock at the source, density ρ, specific heat c, due to the development of q calories of heat per sq. cm. per sec. on the plane, $x = x'$.

The permanent source and sink resulting from (5) is

$$v_2 = \frac{v_q}{2\sqrt{\pi\kappa}}\int_0^t \frac{e^{-\frac{(x'+x)^2}{4\kappa(t-t')}}\,dt'}{\sqrt{t-t'}} - \int_0^t \frac{e^{-\frac{(x'-x)^2}{4\kappa(t-t')}}\,dt'}{\sqrt{t-t'}} \tag{7}$$

To integrate (7), put

$$\beta^2 = \frac{(x'-x)^2}{4\kappa(t-t')} \qquad \beta^2 = \frac{(x'+x)^2}{4\kappa(t-t')}$$

then we have

$$dt' = 2(t-t')\frac{d\beta}{\beta} \qquad dt' = 2(t-t')\frac{d\beta}{\beta}$$

Substituting these expressions in the respective terms of (7),

$$v_2 = \frac{v_q}{2\kappa\sqrt{\pi}}\left[(x'-x)\int_{\frac{x'-x}{2\sqrt{\kappa t}}}^{\infty}\frac{e^{-\beta^2}\,d\beta}{\beta^2} - (x'+x)\int_{\frac{x'+x}{2\sqrt{\kappa t}}}^{\infty}\frac{e^{-\beta^2}\,d\beta}{\beta}\right] \tag{8}$$

in which the indeterminate form in the upper limit has been put equal to ∞.

Making use of the relations,

$$\int_x^\infty x^n e^{-ax^2}\,dx = +\frac{1}{2a}x^{n-1}e^{-ax^2} +$$

$$\frac{n-1}{2a}\int_x^\infty x^{n-2}e^{-ax^2}\,dx. \quad a = 1; n = 0$$

and

$$2\int_x^\infty e^{-z^2}\,dx = \sqrt{\pi}\cdot\frac{2}{\sqrt{\pi}}\int_x^\infty e^{-z^2}\,dx$$

$$= \sqrt{\pi} = \sqrt{\pi}\cdot\frac{2}{\sqrt{\pi}}\int_0^x e^{-z^2}\,dx$$

we have for the integral

$$v_2 = v_q\left\{\frac{\sqrt{t}}{\sqrt{\pi\kappa}}\left[e^{-\frac{(x'-x)^2}{4\kappa t}} - e^{-\frac{(x'+x)^2}{4\kappa t}}\right]\right.$$

$$+\frac{x}{\kappa} + \frac{(x'-x)}{2\kappa}\cdot\frac{2}{\sqrt{\pi}}\int_0^{\frac{(x'-x)}{2\sqrt{\kappa t}}} e^{-\beta^2}\,d\beta$$

$$\left.-\frac{(x'+x)}{2\kappa}\cdot\frac{2}{\sqrt{\pi}}\int_0^{\frac{x'+x}{2\sqrt{\kappa t}}} e^{-\beta^2}\,d\beta\right\}$$

$$= v_q\,\alpha$$

in which the contribution from the source is (9)

$$u_1 = v_q\left[\frac{\sqrt{t}}{\sqrt{\pi\kappa}}\,e^{-\frac{(x'-x)^2}{4\kappa t}} - \frac{(x'-x)}{2\kappa}\right.$$

$$\left.+\frac{(x'-x)}{2\kappa}\cdot\frac{2}{\sqrt{\pi}}\int_0^{\frac{(x'-x)}{2\sqrt{\kappa t}}} e^{-\beta^2}\,d\beta\right] \qquad (10)$$

and the same for the sink is

$$u_2 = v_q\left[\frac{\sqrt{t}}{\sqrt{\pi\kappa}}\,e^{-\frac{(x'+x)^2}{4\kappa t}} - \frac{(x'+x)}{2\kappa}\right.$$

$$\left.+\frac{(x'+x)}{2\kappa}\cdot\frac{2}{\sqrt{\pi}}\int_0^{\frac{(x'+x)}{2\sqrt{\kappa t}}} e^{-\beta^2}\,d\beta\right] \qquad (11)$$

As the numerical value of u_1 in the negative portion of the plane is the same as that of u_2 in the positive portion of the plane, it follows that our problem is the same as that of a source at $x = x'$ and a perfect absorber of heat at $x = 0$ in the sense that the heat which reaches the surface of the ground is lost to the system. In their interesting and

important researches on the diffusion of substances, Stefan[3] and Roberts-Austen[4] assumed that a plane surface perpendicular to the x-axis at the origin acts as a perfect reflector in which case that portion of the curve in the negative part of the plane is considered to be positive instead of negative.

The required temperature is

$$v = v_1 + v_2 \tag{12}$$

The value of the time required in computing v_1 from (4) is $t_1 + t$. Making the appropriate substitutions in (4) and (9) it is found that all of the conditions in (1) are satisfied and as each source and sink is an integral of (2), it follows that the summation of these terms likewise satisfies (2). Carslaw[5] gives a solution similar to (12) when the source $\phi(t)$ is at the origin. Wright[6] discusses the same problem when the initial temperature of the semi-infinite solid is zero.

Equation (9) holds between the limits $x = o$ and $x = x'$. Interchanging x and x' in (8) and carrying out the usual integrations, we have

$$v_2 = u_1 - u_2 = v_q \left\{ \frac{\sqrt{t}}{\sqrt{\pi\kappa}} \left[e^{-\frac{(x-x')^2}{4\kappa t}} - e^{-\frac{(x+x')^2}{4\kappa t}} \right] + \frac{x'}{\kappa} + \frac{(x-x')}{2\kappa} \cdot \frac{2}{\sqrt{\pi}} \int_0^{\frac{x-x'}{2\sqrt{\kappa t}}} e^{-\beta^2} d\beta - \frac{(x+x')}{2\kappa} \cdot \frac{2}{\sqrt{\pi}} \int_0^{\frac{x+x'}{2\sqrt{\kappa t}}} e^{-\beta^2} d\beta \right\} \tag{13}$$

Equation (13) is to be used instead of equation (9) between the limits $x = x'$ and $x = +\infty$. In the limit, when $t = \infty$, equations (9) and (13) give for the final temperature distribution

$$v = v_q x/\kappa \qquad x = 0 \text{ to } x = x' \tag{9a}$$

$$v = v_q x'/\kappa \qquad x = x' \text{ to } x = \infty \tag{13a}$$

[3] M. J. Stefan. *Über die Diffusion der Flüssigkeiten.* K. Akad. Wiss. Wien. Sitzungsber. **79:** 161–214. 1879.

[4] W. C. Roberts-Austen. *On the diffusion of metals.* Roy. Soc. London Phil. Trans. **187***A*: 383–415. 1896.

[5] H. S. Carslaw. *The conduction of heat.* (Macmillan Co. 1921.) p. 173.

[6] C. E. Wright. *Note on a problem in the conduction of heat.* Phil. Mag. **12:** 1015–1019. 1931.

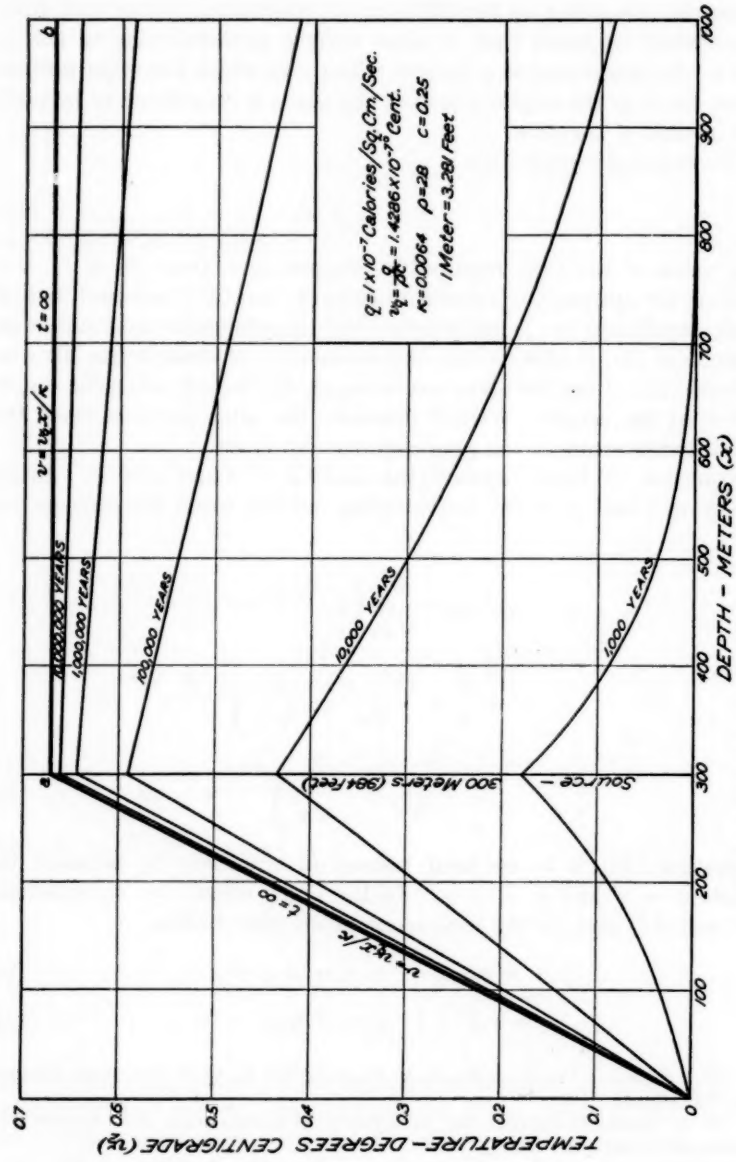

Fig. 1.—Rise in temperature due to a heat source at depth of 300 meters

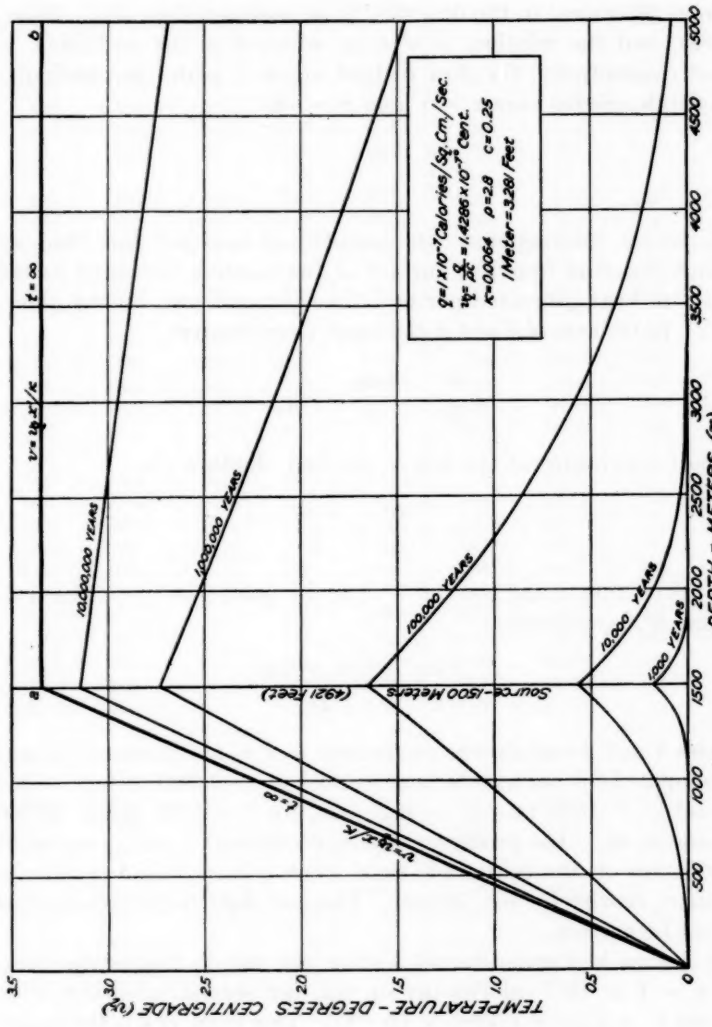

Fig. 2.—Rise in temperature due to a heat source at depth of 1500 meters

These equations are represented in Figures 1 and 2 by the respective lines, *oa* and *ab*. In the latter case, $\partial v/\partial x = 0$, and heat has ceased to flow from the source in the direction of increasing values of x. From (6), (9*a*), and the relation, $\kappa = k/\rho c$, where k is the coefficient of thermal conductivity, the flow of heat across a plane perpendicular to the depth axis between $x = x'$ and $x = o$ is

$$k\frac{\partial v}{\partial x} = \frac{kv_q}{\kappa} = q$$

that is, in the limiting state, the quantity of heat per unit time per unit area escaping from the surface of the earth is the same as the quantity of heat generated per unit time per unit area on the plane, $x = x'$. In the case of a bed of thickness n centimeters,

$$k\frac{\partial v}{\partial x} = \frac{knv_q}{\kappa} = nq$$

and the temperature at the top of the bed, depth x', is

$$v = x'\frac{\partial v}{\partial x} = \frac{x'nq}{k}.$$

From the bottom of the bed, $x' + n$, to the point $x = +\infty$, the temperature is approximately

$$v = \frac{x'nq}{k} + \frac{n(n+1)q}{2k}.$$

Tables 1 and 2 contain the coefficients α of v_q in equations (9) and (13) computed for permanent heat sources at $x' = 300$ meters $= 984$ feet, and $x' = 1500$ meters $= 4921$ feet, for $t = 1000$ years, 10,000 years and so on. The products of these coefficients α and v_q represent temperatures on the centigrade scale when q is expressed in calories per square centimeter per second. The last digit in the tabulations may not be correct.

The curves in Figures 1 and 2 show the rise in temperature (v_2) when $q = 1 \times 10^{-7}$ calories per sq. cm. per second, $\rho = 2.8$, $c = 0.25$, and $v_q = q/\rho c = 1.4286 \times 10^{-7}$°C. This value of q is the equivalent of 3.156 calories per year which is a close approximation to the value of 3.0 calories per year obtained by Richardson and Wells[7]

[7] L. T. Richardson and R. C. Wells. *The heat of solution of some potash minerals.* This Journal, **21**: 243–248. 1931.

TABLE 1. VALUES OF α. $x' = 300$ METERS = 984 FEET.

DEPTH		$\alpha \times 10^{-3}$			DEPTH		$\alpha \times 10^{-3}$	
Meters	Feet	1,000 years	10,000 years	100,000 years	Meters	Feet	1,000,000 years	10,000,000 years
0	0	0	0	0	0	0	0	0
100	328	237	997	1377	300	984	4511	4632
200	656	617	2007	2755	500	1640	4393	4594
225	738	749	2263	3099	1000	3281	4101	4501
250	820	898	2521	3442	1500	4921	3816	4408
275	902	1065	2781	3788	2000	6562	3530	4318
300	984	1252	3042	4133	2500	8202	3254	4225
325	1066	1066	2916	4087	3000	9842	2986	4132
350	1148	900	2791	4041	3500	11483	2728	4040
375	1230	753	2669	3996	4000	13123	2481	3948
400	1312	623	2550	3951	4500	14764	2246	3857
500	1640	264	2101	3770	5000	16404	2023	3767
600	1968	94	1700	3591	5500	18045	1814	3676
700	2297	27	1351	3415	6000	19685	1619	3587
800	2625	7	1053	3242	6500	21325	1440	3499
900	2953	1	806	3073	7000	22966	1270	3411
1000	3281	0	605	2907	7500	24606	1116	3324
1100	3609		445	2745	8000	26247	976	3237
1200	3937		251	2587	8500	27887	849	3152
1300	4265		227	2434	9000	29527	735	3067
1400	4593		157	2286	9500	31168	633	2984
1500	4921		106	2143	10000	32808	542	2901
1600	5249		71	2005	10500	34449	461	2819
1700	5577		46	1872	11000	36089	393	2738
1800	5905		29	1745	11500	37730	328	2658
2000	6562		11	1507	12000	39370	276	2579
2500	8202		0	1009	13000	42651	192	2428
3000	9842			643	14000	45932	130	2279
3500	11483			388	15000	49212	85	2135
4000	13123			221	20000	65617	7	1498
4500	14764			121	25000	82021	1	1001
5000	16404			62	30000	98425	0	635
5500	18045			30	35000	114829		382
6000	19685			14	40000	131233		221
6500	21325			7	45000	147637		120
7000	22966			2	50000	164042		61
7500	24606			1	60000	196850		16
8000	26247			0	70000	229658		5
					80000	262467		2
					90000	295275		1

TABLE 2. VALUES OF α. $x' = 1500$ METERS $= 4921$ FEET.

DEPTH		$\alpha \times 10^{-3}$			DEPTH		$\alpha \times 10^{-3}$	
Meters	Feet	1,000 years	10,000 years	100,000 years	Meters	Feet	1,000,000 years	10,000,000 years
0	0	0	0	0	0	0	0	0
250	820	0	83	1784	500	1640	6356	7347
500	1640	0	243	3594	1000	3281	12721	14696
750	2461	0	580	5458	1500	4921	19104	22046
1000	3281	7	1222	7399	2000	6562	17700	21581
1250	4101	161	2311	9437	2500	8202	16330	21120
1400	4593	623	3229	10715	3000	9842	15000	20660
1500	4921	1253	3962	11592	3500	11483	13719	20201
1550	5085	901	3583	11257	4000	13123	12490	19744
1600	5249	623	3229	10928	4500	14764	11319	19289
1650	5413	415	2900	10603	5000	16404	10211	18837
1700	5577	264	2594	10284	5500	18045	9169	18387
1750	5741	161	2311	9971	6000	19685	8193	17941
1800	5905	94	2051	9663	6500	21325	7287	17497
1900	6234	27	1596	9064	7000	22966	6449	17058
2000	6562	7	1222	8489	7500	24606	5680	16623
2100	6890	1	919	7936	8000	26247	4977	16192
2200	7218	0	680	7408	8500	27887	4339	15765
2250	7382		580	7152	9000	29527	3765	15342
2300	7546		493	6902	10000	32808	2789	14510
2500	8202		246	5962	11000	36089	2024	13699
2600	8530		168	5526	12000	39370	1438	12910
2700	8858		113	5113	13000	42651	1000	12145
2750	9022		92	4915	14000	45932	681	11400
3000	9842		30	4008	15000	49212	454	10683
3250	10663		9	3232	16000	52493	296	9992
3500	11483		2	2575	17000	55774	187	9332
3750	12303		0	2029	18000	59055	117	8694
4000	13123			1579	19000	62336	71	8083
4500	14764			923	20000	65617	44	7505
5000	16404			514	25000	82021	2	5016
5500	18045			272	30000	98425	0	3185
6000	19685			137	35000	114829		1917
6500	21325			65	40000	131233		1097
7000	22966			29	45000	147637		596
7500	24606			12	50000	164042		303
8000	26247			5	60000	196850		63
9000	29527			1	70000	229658		12
10000	32808			0	80000	262467		4
					90000	295275		4

as a possible value of the annual quantity of heat absorbed in the potash beds in Texas and New Mexico. For any other value of v_q, say v_q', and the same thermal constants, it is only necessary to multiply the ordinates of the curve by v_q'/v_q. In the case of absorption of heat, v_2 in (12) is negative.

With increasing depth of source, the curves for short intervals of time tend to become more and more symmetrical. The maximum temperature towards which the source constantly approaches is $v_q x'/\kappa$. These maxima are obviously points on the straight line, $v = v_q x/\kappa$.

For large values of v_q, and small intervals of time t, the curves show that the quantities v_2 which are to be added to or subtracted from the depth-temperature curve v_1 increase rapidly as the source is approached, showing a marked convexity of the curve towards the depth-axis, after which they drop less rapidly to a zero value. A large abnormality of this kind superposed on the depth-temperature curve v_1, which is practically a straight line, should be capable of detection in the field; but, with increasing time, regardless of the value of v_q, that portion of the curve over which it is possible to make observations is also very nearly a straight line, consequently, the final temperature distribution is the sum or difference of two linear distributions. In the case, therefore, of long intervals of time, the only evidence of a heat generating source in approaching an oil-bearing bed or other heat generating stratum is the large value of the gradient, or the small value of the reciprocal gradient. The only criterion that can be applied in this case is the comparison of gradients over the oil-bearing and the adjacent non-oil-bearing area. With sufficient care in obtaining true rock temperatures, the validity or invalidity of the hypothesis should be capable of experimental confirmation. The effect of the heat generating source would be greatly magnified by erosion and steeply tilted beds.

I am greatly indebted to my assistant, Mr. H. Cecil Spicer, for the exceptional care and skill with which he has evaluated equations (9) and (13) for me. The results are summarized in Tables 1 and 2 and represented graphically in Figures 1 and 2.

GEOCHEMISTRY.—*Hydrogen-ion concentrations caused by the solution of silicate minerals.*[1] R. E. STEVENS, U. S. Geological Survey. (Communicated by R. C. WELLS.)

Hydrogen-ion concentration has been found to be an important factor in chemical equilibria of all kinds and its applications to biology, industrial chemistry, agriculture, physiology, bacteriology, and other fields, have been numerous and of great value.[2] Its importance in geochemistry seems obvious but here the influence of hydrogen-ion concentrations has been little considered. Recently W. R. G. Atkins[3] discussed its importance in this field and made a number of preliminary measurements on rocks and minerals. The hydrogen-ion concentration, or pH, largely determines the composition, and perhaps in many cases the crystal form, of minerals separating from solution. Alteration and corrosion are likewise affected by pH. Inorganic reactions of all kinds are dependent on hydrogen-ion concentrations; examples of particular interest to geology are the relations in sulphide and carbonate equilibria. The coagulation of colloidal material held in solution may also be caused by change in pH. Alkalinity or acidity, conveniently expressed in terms of pH, plays an important rôle in geochemical changes.

Waters percolating through the earth's crust become acid or alkaline owing to materials dissolved from the rocks, and if an abundance of a certain mineral is encountered equilibrium is established with this mineral, resulting in a definite equilibrium pH. The effectiveness of each mineral would be dependent upon its ease of attack and abundance. The earth's crust is largely composed of silicate minerals and they would play a major part in maintenance of pH. F. W. Clarke[4] says, "In the solid crust of the earth the silicates are by far the most important constituents. They form at least nine-tenths of the entire known mass and practically all the rocks except the sandstones, quartzites, and carbonates . . . ."

[1] Received August 17, 1932. Published by permission of the Director, U. S. Geological Survey. A more extended paper dealing with this subject entitled "Studies on the alkalinity of some silicate minerals" will be published by the Geological Survey in Professional Paper **175**.

[2] See CLARK, W. M., The determination of hydrogen ions, p. 549, Williams and Wilkins, Baltimore. 1928.

[3] ATKINS, W. R. G. *Some geochemical applications of measurements of hydrogen ion-concentration.* Royal Dublin Soc. Sci. Proc. **19**: 455–460. 1930.

[4] CLARKE, F. W. *The constitution of the natural silicates.* U. S. Geol. Survey Bull. **588**: 5. 1914.

[5] See for example BOUYOUCOS, G. J. *Rate and extent of solubility of minerals and rocks under different treatments and conditions.* Michigan Agr. Exper. Sta. Tech. Bull. **50**. 1921.

That silicate minerals are attacked by water has been shown by field observations, and laboratory measurements[5] have revealed, in a general way, the extent and mechanism of the process. The mineral does not dissolve as a unit but by hydrolysis the alkali is taken into solution, leaving colloidal complexes of silica and alumina. The solutions, therefore show a high pH well on the alkaline side. Many of these minerals give much more alkaline solutions than do the carbonates, calcite and dolomite, although the importance of silicate minerals as sources of alkali has seldom been considered.

Because the discussion of hydrogen-ion concentrations involves principles not as yet broadly applied to geology, it seems wise to explain these briefly.

Water ionizes to a limited extent to give hydrogen and hydroxyl-ions thus:

$$HOH \rightleftharpoons H^+ + OH^-$$

The extent of this reaction is slight but definite, and in pure water the number of hydrogen-ions would be the same as the number of hydroxyl-ions. When other substances in the water are present, however, there is usually more of one than the other of these ions, and use is then made of the fact, based on the law of mass action, that the product of the concentration of H^+ and OH^- is a constant, K_w. That is, $K_w = [H^+]\,[OH^-]$, where the bracketed quantities represent concentrations or activities. In pure water at 25°C. each ion, H^+ and OH^-, is present in a concentration of 1×10^{-7} gram ion per liter, so that $K_w = 1 \times 10^{-14}$. By adding acids the hydrogen-ion concentration is increased and the hydroxyl-ion concentration is decreased proportionately, maintaining the constancy of K_w. Strong acids are highly ionized, giving a large hydrogen-ion concentration, and nitric, sulphuric, and hydrochloric are among these. Weak acids, that are feebly ionized, are acetic and silicic. In like manner alkali increases the hydroxyl-ion concentration. Alkali and alkaline earth hydroxides are strong bases while ammonium hydroxide is a typical weak one.

The constancy of K_w makes it possible to express the concentration of both of these ions by merely stating the hydrogen-ion concentration. By expressing this in terms of pH, where $pH = \log \frac{1}{[H^+]}$, the fractional figures for hydrogen-ion concentrations are reduced to simple whole numbers. As the hydrogen-ion concentration of pure water is 1×10^{-7}, water or neutral solutions are at pH = 7, acid solutions are at pH less than 7, and alkaline solutions at pH greater than 7.

The hydrolysis of silicate minerals is simply illustrated by the reaction of water with wollastonite, $CaSiO_3$, shown in the following equation:

$$CaSiO_3 + 2HOH \rightleftharpoons Ca(OH)_2 + H_2SiO_3$$

The silicic acid thus formed has but little effect on pH as it is weakly ionized and largely precipitated as SiO_2. Calcium hydroxide is a strong base, however, and it is almost completely ionized so that the dilute solution thus produced is strongly alkaline. Thus wollastonite was found to generate a high pH (11.17) when acted upon by water.

These measurements of mineral pH are a rough index of the amount of decomposition taking place and of the relative stability of the mineral in water. This follows also as a result of the law of mass action, for solutions containing a large concentration of hydroxyl-ions derived from relatively soluble minerals would inhibit further formation of that ion from the decomposition of more stable minerals and thus prevent their solution by hydrolysis.

Numerous methods were tried in preparing these solutions of silicates. Owing to the protective action of the colloids of silica and alumina formed, it was necessary to expose as large a surface as possible to water and to remove these protective films. Methods consisting of boiling and of churning the water containing finely ground minerals produced results that were considered too low and that could not be duplicated. By grinding the mineral to a heavy suspension with a few drops of water in an agate mortar a maximum pH seemed to be reached after two minutes of grinding and check determinations showed close agreement. Furthermore the mineral was so easily attacked in this way that an acid buffer solution could be quickly made alkaline, approaching closely the pH obtained when the mineral was ground in pure water.

The colorimetric determinations were made by grinding the mineral for two minutes with one drop of water free from carbon dioxide and one drop of the appropriate indicator solution and comparing the color produced with that of a standard buffer solution of known pH, containing an equal quantity of the indicator. The quantity of mineral used had no measurable effect on the results, provided there was sufficient to give a heavy suspension. It was found that the color comparison could best be made by drawing the solution by capillarity into glass tubes of 1 mm. bore, keeping them upright for about a minute to allow mineral particles to settle as much as possible, and comparing

TABLE 1. RESULTS OF COLORIMETRIC DETERMINATIONS

Index No.		Source	Composition	pH
1	Beryl	Connecticut	$Be_3Al_2Si_6O_{18}$	7.2
2	Genthite	...	$Ni_2Mg_2Si_4O_{10}\cdot 6H_2O$	7.8
3	Lepidolite	...	$KLi[Al(OH,F)_2]Al(SiO_3)_3$	8.4
4	Philipsite	...	$(K_2,Ca)Al_2Si_4O_{12}\cdot 4\frac{1}{2}\ H_2O$	8.4
5	Stilbite	Mexico	$(Na_2,Ca)Al_2Si_6O_{16}\cdot 6H_2O$	8.6
6	Muscovite No. 1	Utah	$H_2KAl_3(SiO_4)_3$, Sericite, fine powdery variety	7.8
7	Do No. 3	...	Do	8.4
8	Do No. 6	...	Do	8.5
9	Do No. 2	...	Do	8.6
10	Do No. 5	...	Do	8.7
11	Do No. 4	...	Do	9.0
12	Calamine	...	$(ZnOH)_2\ SiO_3$	8.8
13	Biotite	Philadelphia	$(H,K)_2(Mg,Fe)_2Al_2(SiO_4)_3$	9.0
14	Pollucite	Buckfield, Me.	$H_2Cs_2Al_2(SiO_3)_5$	9.0
15	Anthophyllite	Montana	$(Mg,Fe)SiO_3$	9.0
16	Laumontite	Mordon, N. S.	$H_4CaAl_2Si_4O_{14}\cdot 2H_2O$	9.0
17	Orthoclase No. 2	Maine	$KAlSi_3O_8$	8.8
18	Do No. 1	Deadwood, S. Dak.	Do	9.2
19	Spodumene	Maine	$LiAl(SiO_3)_2$	9.2
20	Clinochlore	Chester County, Pa.	$H_8Mg_5Al_2Si_3O_{18}$	9.2
21	Albite No. 1	...	$NaAlSi_3O_8$	9.4
22	Do No. 2	...	Do	9.7
23	Wyomingite (Leucite)	Wyoming	$KAl(SiO_3)_2$ (?)	9.4
24	Labradorite No. 2	...	$NaAlSi_3O_8\cdot 3CaAl_2Si_2O_8$ (?)	9.4
25	Do No. 1	...	Do	9.8
26	Margarite	Chester, Mass.	$H_2CaAl_4Si_2O_{12}$	9.8
27	Natrolite	...	$Na_2Al_2Si_3O_{10}\cdot 2H_2O$	10.0
28	Epidote	...	$Ca_2(Al\cdot OH)(Al, Fe)_2(SiO_4)_3$ Varies	10.0
29	Actinolite	Roan Mtn., Tenn.	$Ca(Mg,Fe)_3(SiO_3)_4$	10.0
30	Phlogopite	...	$H_2KMg_3Al(SiO_4)_3$ (?)	10.1
31	Diopside	...	$CaMg(SiO_3)_2$	10.1
32	Hornblende	...	$CaMg_3(SiO_3)_4$ with $Na_2Al_2(SiO_3)_4$ + $Mg_2Al_4(SiO_6)_2$	10.2
33	Olivine	Willits, N. C.	$(Mg,Fe)_2SiO_4$	10.2
34	Thulite	...	$HCa_2Al_2Si_3O_{12}$	10.2
35	Talc	Edwards, N. Y.	$H_2Mg_3(SiO_3)_4$	10.2

TABLE 1. RESULTS OF COLORIMETRIC DETERMINATIONS—*Concluded*

Index No.			Source	Composition	pH
36	Pyroxene		...	$Ca(Mg,Fe)(SiO_3)_2$	10.2
37	Tremolite	No. 1	...	$H_2Ca_2Mg_5(SiO_3)_8$	10.2
38	Do	No. 2	...	Do	10.2
39	Pectolite		...	$HNaCa_2(SiO_3)_3$	10.4
40	Prehnite	No. 3		$H_2Ca_2Al_2Si_3O_{12}$	10.2
41	Do	No. 2	Michigan	Do	10.4
42	Do	No. 1	...	Do	10.5
43	Apophyllite	No. 1	...	$H_7KCa_4(SiO_3)_8 \cdot 4\frac{1}{2}\ H_2O$	10.4
44	Do	No. 2	...	Do	10.4
45	Wollastonite		...	$CaSiO_3$	10.8
46	Glass	No. 106[a]	...	SiO_2 75.48; Na_2O 15.26; CaO 9.26	11.2
47	Do	No. 135[a]	...	SiO_2 78.40; Na_2O 16.17; CaO 0.21; MgO 5.22	11.4

[a] Analysis by F. W. GLAZE, U. S. Bureau of Standards.

colors against a white background in indirect sunlight. For certainty, colors were duplicated several times and whenever possible checks were run using different indicators. The indicators and buffer solutions were selected from Clark's treatise, "The determination of hydrogen ions."

Colorimetric determinations on representative minerals are given in Table 1. The results are in good accord with field observations on the stability of these minerals and a relation to composition may be seen—the highly basic minerals giving a high pH. Tests on different samples of the same mineral (see muscovite, orthoclase, albite, labradorite, tremolite, prehnite, and apophyllite) show a rather limited range of pH for the same mineral and, it is judged, differences are due to impurities, incipient alteration, possible varieties in the species, and similar variations inherent in natural products. The alkalinity found for calamine in particular seems the result of impurities and not of its true composition. Nevertheless, the results as a whole show a remarkable gradation of pH between those minerals that are easily attacked by water and those that are relatively stable.

The determinations on glass might be of interest to glass technologists. Results on two glasses of known composition are shown at the end of Table 1. Glasses tested having a higher content of alkali than these gave pH figures above 12 and could not be readily measured, while pyrex glass gave about pH = 8. This pyrex glass and the more

alkaline ones tested represent extremes of durability and show wide contrast in the test. The results for glass are of interest to mineralogists in that they show the effect of increased alkali content.

A more quantitative study of pH of a selected group of the minerals was made with the hydrogen electrode. Because the volume of solution prepared from the minerals was small a microelectrode was used. A simplified form of the one described by Bodine and Fink[6] was found to give good results. The hydrogen was generated electrolytically from caustic soda solution and passed over copper gauze at 500°C. before entering the electrode vessel. For the preliminary measurements a normal calomel half cell served as reference electrode but in most of the measurements the tenth normal electrode, recommended by Clark, was used instead. A saturated potassium chloride

TABLE 2. EFFECT OF CARBON DIOXIDE ON pH
MATERIAL USED, GLASS NO. 135

(TWO MINUTE GRINDINGS, NORMAL CALOMEL ELECTRODE USED)

1. GROUND IN AIR

Temperature	25°C.	25°C.	26°C.	28°C.
E. M. F.	0.9468	0.9555	0.9491	0.9490
pH	11.21	11.36	11.21	11.15
Average pH	11.23	Maximum deviation		0.13

2. GROUND IN NITROGEN FREE FROM CARBON DIOXIDE

Temperature	27°C.	27°C.	27°C.	28°C.	28°C.
E. M. F.	0.9660	0.9675	0.9650	0.9680	0.9710
pH	11.47	11.49	11.46	11.47	11.51
Average pH	11.48	Maximum deviation		0.03	

bridge connected the two electrodes; a thermometer dipping into the potassium chloride showed the temperature at which measurements were made. The e.m.f. of the resulting cell was measured with a Leeds and Northrup, Type K, potentiometer and from this e.m.f. the pH of the solution was calculated.

It was expected that the results determined colorimetrically would be somewhat low, due to the effect of atmospheric carbon dioxide, and this was shown electrometrically by preparing the solutions in nitrogen free from carbon dioxide. A rubber diaphragm was stretched over the top of the mortar, fastened down with *passe-partout*, with small holes for the nitrogen inlet and for insertion of the pestle. The air was

[6] BODINE, J. H. and FINK, D. E. *A simple micro vessel with electrode for determining the hydrogen ion concentration of small amounts of fluid.* Jour. Gen. physiol. **7**: 735. 1925.

TABLE 3. TIME OF GRINDING NEEDED TO REACH EQUILIBRIUM
(NORMAL CALOMEL ELECTRODE USED)

(*a*) ONE MINUTE GRINDING

	Glass No. 135		Spodumene	
Temperature	30°C.	30°C.	30°C.	30°C.
E. M. F.	0.9680	0.9685	0.8280	0.8330
pH	11.40	11.40	9.08	9.15
Average pH	11.40		9.11	

(*b*) TWO MINUTES GRINDING

Temperature	27°C.	27°C.	30°C.	30°C.	30°C.
E. M. F.	0.9660	0.9675	0.8410	0.8450	0.8430
pH	11.47	11.49	9.28	9.35	9.32
Average pH	11.48			9.32	

(*c*) THREE MINUTES GRINDING

Temperature	30°C.	30°C.	31°C.	31°C.	31°C.
E. M. F.	0.9745	0.9760	0.8470	0.8420	0.8430
pH	11.50	11.53	9.36	9.27	9.29
Average pH	11.51			9.31	

TABLE 4. RESULTS OF ELECTROMETRIC MEASUREMENTS

Index No.	Mineral	Colorimetric pH	Electrometric pH	No. of determinations	Maximum deviation from average	Temperature °C.
	Calcite	9.0 (Atkins, 1930)	9.03	2	0.02	25
14	Pollucite	9.0	8.96	2	0.02	26
17	Orthoclase No. 1	9.2	9.18	3	0.03	28
19	Spodumene	9.2	9.31	6	0.05	30–31
22	Albite No. 2	9.6	9.84	2	0.04	28
27	Natrolite	10.0	10.05	2	0.03	28
37	Tremolite No. 1	10.2	10.50	3	0.02	22
38	Do No. 2	10.2	10.17[a]	3	0.06	24
44	Apophyllite No. 2	10.4	10.79	3	0.02	26
45	Wollastonite	10.8	11.17	3	0.01	24
47	Glass No. 135	11.4	11.49	7	0.04	27–30

[a] Probably too low. Contained a trace of iron and 1.15 per cent manganese.

swept out and the diaphragm inflated with nitrogen during grinding of the mineral. One of the more alkaline materials, glass No. 135, was selected for the test, that the effect might be more pronounced, and the results in Table 2 show that carbon dioxide lowered the pH figure by 0.25 pH and caused wide variations. Results where carbon dioxide was eliminated deviate from the average by only 0.03 pH unit. Therefore in all subsequent determinations carbon dioxide was eliminated.

The time of grinding could be extended to three minutes without the solution becoming so thick due to evaporation that measurements could not be made, and results in Table 3 show the effect of one, two, and three minute grindings. These results indicate a close approach to equilibrium in two minutes. All electrometric results were obtained after grinding the mineral in water for two minutes.

Minerals containing oxidizable materials, such as iron, chromium, and manganese, had to be avoided as they caused low electrometric readings.

The results of the electrometric measurements on a number of minerals are given in Table 4. The degree of reproducibility seems remarkable, no determinations varying from the average by more than a few hundredths of a pH. The result for calcite, $CaCO_3$, checks closely the colorimetric determination by Atkins, whose work is referred to early in the text. In general the electrometric and colorimetric results are in fair agreement, small deviations being accounted for largely by the action of carbon dioxide.

Summary

By grinding silicates under water, solutions with characteristic and reproducible pH values have been obtained. The colorimetric and electrometric results show that silicate minerals, when acted on by pure water, give highly alkaline solutions, and their importance as regulators of geochemical changes is indicated. The pH values obtained are a rough index of the weathering qualities of the mineral.

ZOOLOGY.—*A new amphipod of the genus* Leptocheirus *from Chesapeake Bay.*[1] CLARENCE R. SHOEMAKER, U. S. National Museum.
(Communicated by W. L. SCHMITT.)

Recently while studying the amphipods of the genus *Leptocheirus* contained in the National Museum collection, I noted that specimens taken in the upper half of Chesapeake Bay by the U. S. Bureau of Fisheries during its biological survey in 1920 and 1921 belonged to a new and undescribed species, for which I now propose the name *Leptocheirus plumulosus*. The only other species of this genus known from the eastern coast of America, *Leptocheirus pinguis* (Stimpson), is very abundant off the coast of New England and has been recorded from the Gulf of St. Lawrence south to the mouth of Chesapeake Bay (37°N., 74°W.), where a single specimen was taken by the *Albatross* in 1883.

L. plumulosus was taken at six localities ranging from the mouth of the Potomac River northward to the mouth of the Patapsco River, at depths between 9 and 43 fathoms.

The specific name *plumulosus* is given in reference to the extremely feathery appearance of the second joint of the third, fourth, and fifth peraeopods.

Description, male.—Head with lateral angle prominent and broadly rounding. Eye oval, black and rather small. Antenna 1 shorter than antenna 2, first joint stouter and longer than second which is stouter and longer than third, flagellum a little longer than peduncle and composed of about seventeen joints, accessory flagellum about equal in length to third peduncular joint and consisting of four or five joints the last of which is very small. Antenna 2, fourth joint slightly longer than fifth, flagellum shorter than peduncle and consisting of about fourteen joints. Mandible with secondary plate well developed, eight spines in spine-row, molar well developed and bearing a small accessory tooth at its base opposite the spine row, and also a plumose seta at its inner corner; palp with first, second, and third joints increasing slightly in length consecutively. Maxilla 1, inner plate rather long and bearing a single terminal plumose seta; outer plate with eleven serrate spine teeth; palp bearing five apical spines and several setae. Maxilla 2 not differing from that of other species of the genus. Maxillipeds about as figured by Sars for *L. pilosus*.[2] Lower lip with inner and outer lobes well developed, mandibular processes rather small. Side-plate 1 not produced forward, margins slightly converging toward the evenly rounding lower border which is beset with a row of fine plumose setae. Gnathopod 1 robust and strong; fifth and sixth joints about equal in length; sixth joint widening distally, palm slightly oblique with a central concavity, defining angle evenly rounding without defining spine; seventh joint not overlapping palm and with inside edge bearing a row of fine spinules. The first, second, third,

[1] Published by permission of the Secretary of the Smithsonian Institution. Received August 30, 1932.

[2] G. O. SARS. *Crustacea of Norway*, **1**: *pl. 197, fig. mp.*

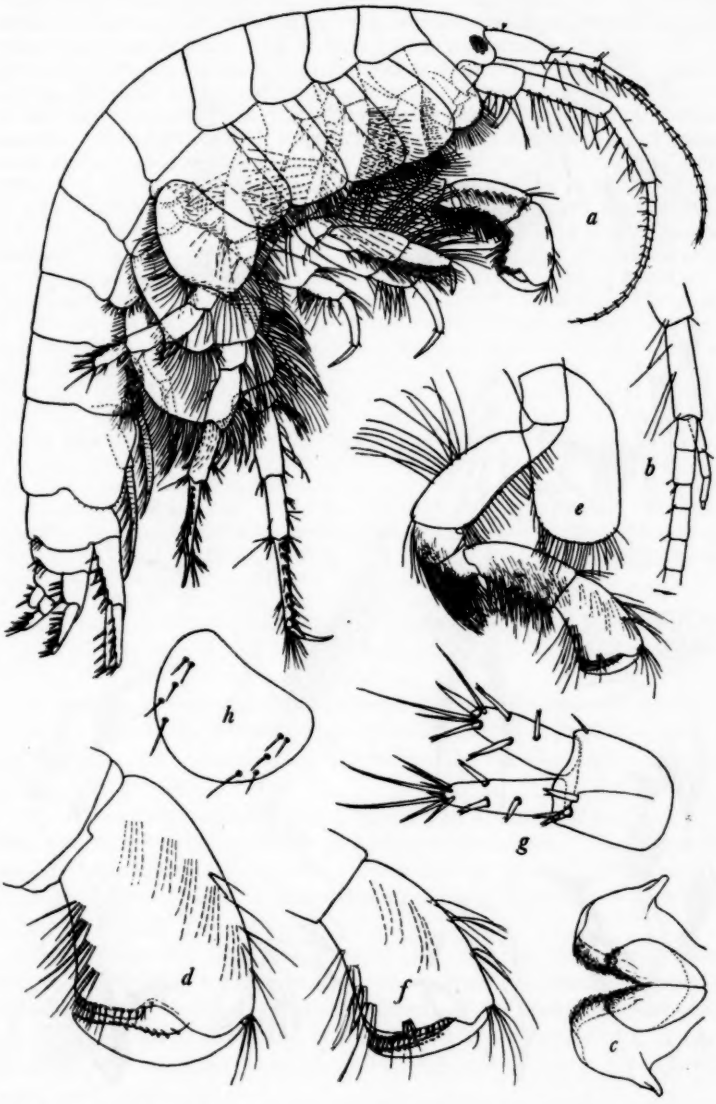

Fig. 1.—*Leptocheirus plumulosus*, new species. Male, *a*, Entire animal. *b*, Accessory flagellum. *c*, Lower lip. *d*, Sixth and seventh joints of gnathopod 1. *e*, Gnathopod 1 of female. *f*, Sixth and seventh joints of gnathopod 1 of female. *g*, Uropod 3, right. *h*, Telson.

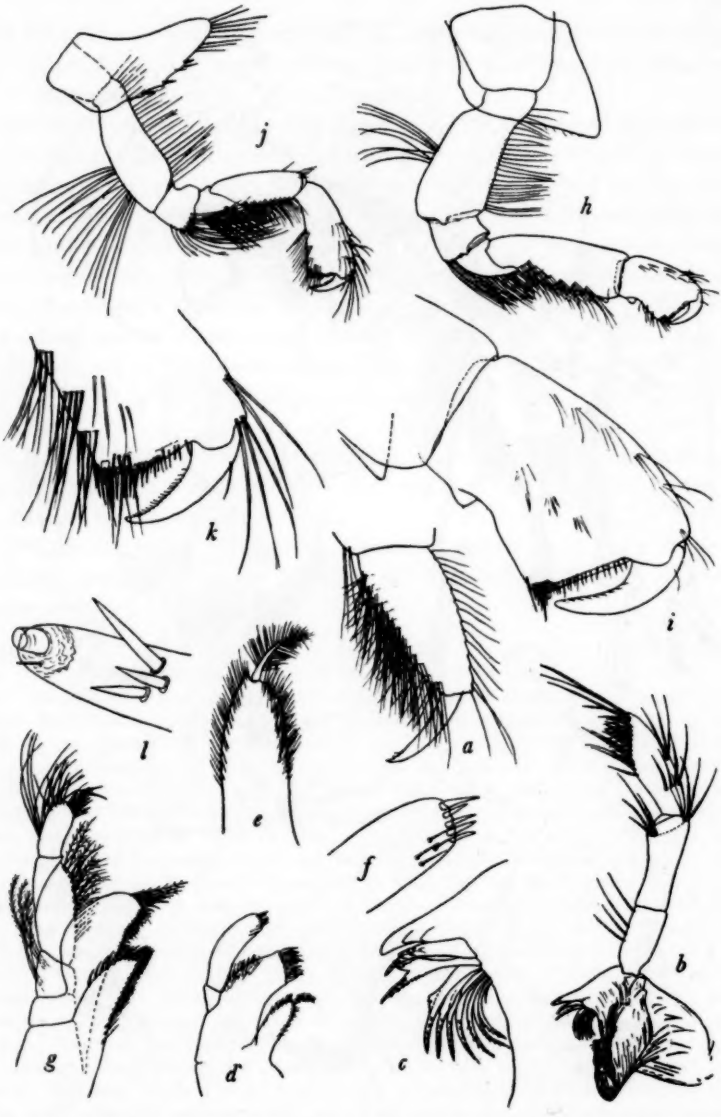

Fig. 2.—*Leptocheirus plumulosus*, new species. Male, *a*, End of gnathopod 2. *b*, Mandible. *c*, Cutting plates and spine-row of mandible. *d*, Maxilla 1. *e*, Inner plate of maxilla 1. *f*, End of palp of maxilla 1. *g*, Maxilliped. *h*, *i*, Gnathopod 1 of *L. pinguis*, male. *j*, *k*, Gnathopod 1 of *L. pinguis*, female. *l*, Outer ramus of uropod 3 of *L. pinguis* showing rudimentary second joint.

and fourth joints of gnathopod 1 are densely beset with groups, bundles, and rows of plumose setae which give them a brush-like appearance; and the sixth joint bears five or six groups of spines on hind margin. Side-plate 2 slightly expanded distally. Gnathopod 2 about as figured by Sars for *L. pilosus*, and having the same armature of plumose setae. Peraeopods 1 and 2 about equal in size and shape and are proportionally as shown in the figure of the entire animal. Side-plate 5 with front lobe as deep as side-plate 4. Peraeopod 3 with the expanded rear margin of second joint produced upward and both front and rear margins bearing a dense row of long plumose setae. Peraeopod 4 with rear margin of second joint less produced upward than 4, front and rear margins edged with long plumose setae. Peraeopod 5 with rear margin scarcely at all produced upward, and somewhat angular, front and rear margins densely edged with long plumose setae. Pleon segments 1 and 2 densely clothed on their lower parts with long, curved, plumose setae. Pleon segment 3 with lateral margin and lower corner evenly rounding and bearing a few fine spinules. Pleon segments 4 and 5 without dorsal teeth but each bearing on either side a row of four spinules on an oblique offset of the lateral margin near the dorsal surface. Uropods 1 and 2 reaching back about the same distance which perhaps is slightly farther than uropod 3. The spine-like apical process of uropods 1 and 2 reaches nearly to the middle of the outer ramus. Uropod 3 with rami short and about equal in length to the peduncle; the outer ramus bears a terminal group of spines of various lengths, but no rudimentary second joint could be observed such as is present in *L. pinguis*. In uropods 1 and 2 the outer ramus is the shorter, but in uropod 3 it is slightly the longer. Telson broader than long, almost evenly rounding posteriorly and bearing about five spinules near either lateral margin.

Length.—Male about 11 mm.; female somewhat less.

Type locality.—*Fish Hawk* station 8963, Chesapeake Bay, Md.: Bloody Pt. 99°; Thomas Pt. Light 15°. March 28, 1921, 9 fathoms. (Cat. No. 66075 U. S. N. M.)

In the female the palm of gnathopod 1 is evenly convex and almost transverse with smoothly rounding defining angle which is preceded by a rather small spine-tooth. In all other characters the female bears a close resemblance to the male.

In *L. plumulosus* antenna 1 is shorter than antenna 2, a character which does not agree with Stebbing's definition of the genus. Neither is there a second rudimentary joint to the outer ramus of uropod 3,[3] but in all other characters there is such a close agreement with *Leptocheirus* that I believe it best to include it in that genus.

In *L. pinguis* the first gnathopod of the male has the palm oblique and about straight with a spine-tooth at the narrowly rounding defining angle; the seventh joint being stout, much curved and the apex only closing against the defining angle of the palm. Gnathopod 1 of the female of *L. pinguis* has the sixth joint much as in the present species except that it is proportionally longer and narrower.

[3] E. W. Sexton. *On the Amphipod genus* Leptocheirus. Proc. Zool. Soc. London. **2**: 562. 1911.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

GEOLOGICAL SOCIETY

492ND MEETING

The 492nd meeting was held at the Cosmos Club, October 12, 1932, President F. E. MATTHES presiding.

Program: P. B. KING: *General structural features of the Cordilleran Province.* —This paper summarizes part of the results of a compilation made for a guidebook of the International Geological Congress on the structural features of the United States. The Cordilleran province, in a structural sense, applies to the area of folded and faulted rocks which lies along the western side of the central stable region of North America. The most active deformation in the province was in later Mesozoic and early Cenozoic time, but there was a complex pre-deformation and post-deformation history. The local geologic history and the effects produced by the deformation are quite different in different parts of the province, so that it is divisible into a number of distinct subdivisions.

(A) Along the west coast is a chain of Coast Ranges, which is a comparatively young feature.

(B) East of the Coast Ranges is a zone of structural features which is typically developed in the Sierra Nevada. It is characterized by batholiths of large size, and by a thick metamorphosed stratigraphic succession composed predominantly of clastic and volcanic rocks and ranging in age from early Paleozoic to Jurassic. This zone was intensely deformed in middle Mesozoic time, and was made rigid enough to transmit a thrust from the west to the next zone to the east.

(C) East of the zone of structural features of Sierra Nevada type is a belt of strong folding and overthrusting, which extends from the northern Rocky Mountains through the Great Basin into the Sierra Madre Oriental of Mexico. The belt is characterized by great thicknesses of sedimentary rocks, which are of different ages in different places. In the northern Rockies the thickest sedimentary rocks are of Algonkian age, in the central Great Basin of early Paleozoic age, in the eastern Great Basin of later Paleozoic age, and in the Sierra Madre of Mesozoic age. The belt is characterized by great overthrust faults which have moved from west to east, which are of early Tertiary age along the eastern margin of the belt. The belt directly faces the Great Plains near the Canadian boundary, and the Gulf Coastal Plain in Mexico. Between these points, plateaus and outer ranges lie in front.

(D) About midway along the length of the Rocky Mountain belt is the Colorado Plateau, a broad positive area which has never been greatly deformed. It has behaved as a rigid area during the Cordilleran deformation, and has transmitted the thrust from the west to the Rocky Mountains of Colorado and Wyoming which lie northeast of it.

(E) The ranges northeast of the Colorado Plateau are for the most part broad open folds which reveal pre-Cambrian crystalline rocks on their crests. In Colorado, however, the relations are more complex. Here there is much more close folding and overthrusting. This is partly because these ranges have been reelevated on the site of old Paleozoic chains, and because of the exceptional thicknesses of Paleozoic intermontane deposits laid down between the earlier ranges.

Study of the Cordilleran province suggests that the motivating forces were compressional forces which originated near the Pacific border, and whose existence was long continued. Sedimentation has been intimately related to the compressional movements, but it was an effect rather than a cause. The character of the sedimentation has strongly influenced the distribution and character of the later structural features. The diverse units of the Cordilleran province appear to have resulted from the interaction of regions of different degrees of competency, under the influence of the thrust from the west. (*Author's abstract.*)

Discussed by Messrs. SPENCER, C. P. ROSS, GILLULY, RESSER, HEWETT, and RUBEY.

K. E. LOHMAN: *Diatoms and their significance in geology.*—The value of diatoms as stratigraphic and ecologic indicators has been greatly neglected by geologists in the past. Diatoms, having siliceous tests, are well preserved under most conditions and their abundance, both as to numbers of species and individuals, makes possible a reasonable understanding of the environmental conditions obtaining during their deposition. Living diatoms occur in many types of habitat, marine, brackish, saline, and fresh water bodies containing unique assemblages varying in quantity from a few hundred cells per liter to more than twelve million. They occur nearly pure in diatomites, less so in diatomaceous shales, clays, mudstones, siltstones, limestones, and calcareous concretions.

Diatoms occur in rocks of all geologic ages from Jurassic to Recent; older occurrences being reported but not sufficiently authenticated. Excellent diatom floras have been obtained from marine Cretaceous, Eocene, Oligocene (?), Miocene, and Pliocene beds in California as well as from non-marine Miocene, Pliocene, and Pleistocene beds in Oregon and Nevada. To cite one example of their value in correlation: The Temblor formation of California, which has been called Middle Miocene on the evidence of molluscs, contains the same short-ranged species of diatoms as the Calvert Formation of Maryland and Virginia, also called Middle Miocene on molluscan evidence. (*Author's abstract.*)

Discussed by Messrs. GOLDMAN, COOKE, CAPPS, R. C. WELLS, STEVENSON, G. R. MANSFIELD, and LADD.

BOTANICAL SOCIETY

ANNUAL OUTING

A special informal field meeting and picnic was held at the Montgomery Sycamore Island Club on the afternoon of June 6, 1931, attendance about 50. Through the courtesy of the Club the grounds were reserved for the Society.

Members and their families botanized, played games, bathed in the Potomac and otherwise amused themselves. About 5 P. M., ice cream was served by the Society, individuals having furnished their own lunches.

235TH MEETING

The 235th regular meeting was held in the Assembly Hall of the Cosmos Club on October 6, 1931. President N. E. STEVENS presided; 51 members and guests were present.

The following were elected to membership: Miss MARY A. BRADLEY, Dr. J. A. FARIS, Miss FALBA L. JOHNSON, and Dr. EARL S. JOHNSTON.

Reports of summer meetings of interest to botanists:

Miss MARY BRYAN.—The Appalachian Trail Conference in the Great Smoky Mountains.

C. L. SHEAR.—The fungous foray at Ithaca.

E. H. TOOLE.—The Sixth International Seed-testing Congress in the Netherlands.

N. E. STEVENS.—The Bartram Memorial Meeting commemorating the 200th anniversary of the first Botanical Garden.

M. C. MERRILL.—Special field meeting of the Botanical Society of Washington.

Brief Notes and Reviews: Doctor WAITE referred to his previous remarks on lily pods and exhibited pods of *Lilium regale* illustrating the special organs for keeping the seed from scattering too soon and for keeping the pod erect.

Program: Wild flowers of the Yosemite Park, a two reel film by A. C. PILLSBURY, shown by P. L. RICKER.

SPECIAL MEETING

A special meeting was held in Room 43 of the New National Museum on October 23, 1931. Attendance, about 60, including guests from the Wild Flower Preservation and from the Biological Societies.

Program: Dr. JAKOB E. LANGE of Denmark.—*Comparative studies of European and American species of mushrooms and toadstools.* The speaker had noticed on a previous trip to the United States that many of the species here were the same as those found in Europe and that some of the species had been named by American investigators on small differences. The fact that it is impossible to make good herbarium specimens of mushrooms and that photographs are inadequate for identification has lead to confusion between American and European mycologists. Printed descriptions of species as well as portraits painted by an artist are of no value for classification. However, colored drawings done by a mycologist are very useful, identification being easily made provided enough species have been illustrated. So far only a few hundred have been drawn by the author. The need for more intensive work is plainly evident. Attention was called to the wonderful opportunity which America has in such a program. Being a large country, under one government and with a common language makes it possible for America to outstrip Europe in the study of the fleshy fungi. Colored drawings of a considerable number of species of mushrooms were exhibited.

NATHAN R. SMITH, *Recording Secretary.*

236TH MEETING

The 236th regular meeting was held in the Assembly Hall of the Cosmos Club on November 3, 1931. President N. E. STEVENS presided; about 80 members and guests were present.

Brief notes and reviews: H. B. HUMPHREY called attention to a Plant Physiology by E. C. MILLER, recently published by McGraw-Hill Book Company. N. A. COBB spoke of the JOURNAL of the WASHINGTON ACADEMY as a very prompt and efficient means of publication for short papers and asked for suggestions from the Society for improvement of the JOURNAL. The motion was made and carried that a committee be appointed to make recommendations and to confer with the editor of the JOURNAL and with Dr. HUMPHREY, the representative of the Society to the Academy. M. B. WAITE remarked on the unusual growth of annual weeds and the late maturing of peaches and other plants. He attributed these to an abnormal amount of nitrates in the soil due to the recent drought.

Program: P. H. DORSETT.—*Open air winter forcing of strawberries in Japan* (illustrated). This unique horticultural practice has been developed locally in Japan during the past twenty-five years with an industry amounting to $35,000 in 1929 and 1930. Stone-faced beds are built at an angle of 45° on terraces up the southern slopes of Mount Kunozan, a day's ride west of Tokio. This method produces berries five times earlier and plants four to five times more prolific than can be produced by other methods.

P. H. DORSETT: *Interesting features of Chinese "Ching Ma".—Abutilon Theophrasti* is a widely distributed weed in this country but in China it is grown for its fiber and stems. The speaker exhibited samples of rope, fire-crackers and charcoal made from this plant. These products are being investigated in the United States as possible sources of a new industry.

CHARLOTTE ELLIOTT, *Corresponding Secretary.*

237TH MEETING

The 237th regular meeting was held in the Assembly Hall of the Cosmos Club on December 1, 1931. President N. E. STEVENS presided; about 105 members and guests were present.

The following were elected to membership: WALTER A. DAVIDSON, OSCAR J. DOWD, F. W. OLDENBURG, and KENNETH B. RAPER.

Program: N. E. STEVENS, Retiring President of the Society.—*The fad as a factor in botanical publications.* This address has been published in full in Science.

Brief Notes and Reviews: Doctor WEISS called attention to the destruction of elms on East Capitol Street and the Ginkgo and other groups in the grounds of the Department of Agriculture. He proposed the following resolution:

WHEREAS: The National Capitol Park and Planning Commission, in the furtherance of its efforts to transform the natural beauty of the Department of Agriculture grounds—a beauty which is derived from the varied contour and the plantings of stately and historic trees—into something of the general topographic and vegetational features of an Illinois prairie to be adorned with four magnificent concrete roadways, has caused the destruction of the famed Ginkgo Avenue in the Agricultural Department grounds,

BE IT RESOLVED, by the Botanical Society of Washington, that cognizance be taken of this act of destruction, and that the regret of the members at the loss of this notable planting of Ginkgo trees and other groups of trees in the Agricultural grounds, be recorded on the minutes of this, the 237th meeting of the Society, and

BE IT FURTHER RESOLVED, that we hereby deprecate the failure of the Park and Planning Commission to realize the possibilities of civic beautification by preserving, so far as possible, natural objects and conditions.

Moved and seconded, that the resolution be adopted. It was discussed by M. B. WAITE and J. B. S. NORTON and then carried.

The meeting then adjourned so that the annual meeting and election of officers might be held.

ANNUAL MEETING

The 31st annual meeting was held immediately following the adjournment of the 237th regular meeting on December 1, 1931.

The Recording Secretary reported that during the past year, eight regular meetings, one buffet dinner with entertainment, one field meeting and picnic and one special meeting were held. The attendance at the regular meetings

were: January, 102; February, 150; March, 200; April, 41; May, 96; October, 51; November, 80; December, 105. Average, 103. Twenty-four new members were elected, two absent members replaced on mailing lists, ten have resigned or have been placed on the absent list, three deaths have occurred, leaving an active membership list of 200.

The Corresponding Secretary read the following list of members who had died during the past three years:

DR. P. A. YODER 1867–July 18, 1929.
Biographical sketch in Journ. Wash. Acad. Sci. **19**: 394. 1929.

DR. W. A. ORTON 1877–January 7, 1930.
Biographical sketch in Phytopathology **21**: 1–11. 1931.

DR. E. G. ARZBERGER 1877–January 29, 1930.
Biographical sketch in Phytopathology **21**: 576. 1931.

DR. F. J. PRITCHARD 1874–January 13, 1931.
Biographical sketch has been submitted for publication in Phytopathology.

DR. W. J. SPILLMAN 1863–July 11, 1931.
Biographical sketch in U. S. Dept. Agric. Official Record **10**: 218. 1931.

DR. R. A. OAKLEY 1880–August 6, 1931.
Biographical sketch in Science **74**: 195. 1931.

The report of the Treasurer was read. The President appointed JOHN STEVENSON and W. A. MCCUBBIN as an auditing committee.

The following officers were elected by ballot:

President—DR. J. B. S. NORTON
Vice President—DR. CHARLES BROOKS
Recording Secretary—NATHAN R. SMITH
Corresponding Secretary—DR. CHARLOTTE ELLIOTT
Treasurer—EDITH CASH
Vice President of the Washington Academy of Sciences—DR. H. B. HUMPHREY.

238TH MEETING

The 238th regular meeting was held in the Assembly Hall of the Cosmos Club on January 5, 1932. President J. B. S. NORTON presided. Attendance about 110.

The following were elected to membership: A. W. SKUDERNA, DR. HOWARD W. JOHNSON, DR. RONALD BAMFORD, and DR. GLENN A. GREATHOUSE.

Brief Notes and Reviews: DR. WAITE exhibited specimens of Bermuda grass which is still green, due to the mildness of the winter. He also exhibited branches cut from peach trees in this locality which showed fewer buds than in normal years. Reports from Illinois, Indiana and California, also indicate that fewer buds are laid down this year than normal. This may in part be due to the heavy crop last year. DR. CHARLES SWINGLE exhibited a species of *Bryophyllum* brought from Madagascar which is still alive outdoors, while specimens of this plant in California had been killed by the cold. Five minute reports on the New Orleans meetings of the American Association for the Advancement of Science were given by DR. N. E. STEVENS and OSCAR J. DOWD.

Program: LEE M. HUTCHINS.—*Phony Peach: Some new departures in a virus disease.* (illustrated). Peach trees affected with this disease have a darker green color, are more dense and produce much smaller fruit. The disease has been slowly spreading and has resulted in great losses in certain localities. Experiments, involving thousands of grafts of roots and scions, to determine the cause of this disease were discussed. The fact was finally established that this virus disease is localized in the roots, the trunks and limbs being free of the infective agent. The means by which this disease is spread has not yet been determined. Discussed by DR. WAITE, DR. KELLERMAN, DR. TAYLOR, and others.

239TH MEETING

The 239th regular meeting was held on February 2, 1932, in the Assembly Hall of the Cosmos Club, attendance 83.

DR. M. C. GOLDSWORTHY was elected to membership.

Brief notes and reviews: DR. J. S. COOLEY exhibited a culture of *Xylaria malli* which showed phototropium. DR. HITCHCOCK reported on the examination of material suspended in the air as caught by air-planes. One half of the fifty specimens contained seeds of Vasey grass whereas the light fluffy seeds were not found. DR. NORTON called attention to a host index of rusts and also to a list of forty-seven species of plants found blooming in December and January of this winter. DR. WAITE called attention to a publication in the Geographical Review dealing with the climates of North America in which many interesting points are brought out including a map of the climates. DR. THONE exhibited the new address book of botanists, a textbook of botany by Coulter, Barnes, and Cowles and a German treatise, Arbeiten über Kalidungung.

Program: M. C. GOLDSWORTHY.—*The effect of smelter smoke upon plants.* (illustrated). G. G. HEDGCOCK: *Crop plants; Forest vegetation.* The data presented by both speakers will be published later.

SPECIAL MEETING

A special meeting was held on February 16, 1932, in the Auditorium of the Interior Department; attendance about 160.

Program: E. V. ABBOTT.—*Travels in Peru.*—The talk was illustrated by lantern slides showing the agriculture, Indian life and scenic beauties of the country.

Following the talk, several members asked questions of the speaker and DR. HITCHCOCK spoke briefly of his travels through the same region.

NATHAN R. SMITH, *Recording Secretary.*

SCIENTIFIC NOTES AND NEWS

Prepared by Science Service

NOTES

Public Health Service officers speak.—The meeting of the New York Electrical Society on the evening of November 16 was devoted mainly to the U. S. Public Health Service. Among the speakers were Dr. R. E. DYER, Surgeon General HUGH S. CUMMING, and Prof. CARL VOEGTLIN. Dr. DYER's appearance was his first since he contracted an attack of endemic typhus fever in the course of his studies of the etiology of that disease. He spoke, appropriately, on the history of the fight against typhus in this country. Surgeon General CUMMING devoted most of his address to a description of the new U. S. National Institute of Health. He also outlined the combination of laboratory and field work involved in the attack on certain diseases, such as malaria. Prof. VOEGTLIN presented the results of his chemical investigation into the physiology of cancer tissue. In an atmosphere of nitrogen, the albumen of both cancerous and normal cells breaks down, he said, while in the presence of oxygen it is restored. Low concentrations of copper and lead inhibit the growth of cancer tissue; no other metals in the same concentrations affect it.

More Eskimo archaeology.—Two expeditions of the U. S. National Museum which have been investigating Eskimo archaeology during the past season have returned, both reporting gratifying results. Dr. ALEŠ HRDLIČKA brought back much skeletal material and many artifacts, some of them of real beauty, considering the obdurate materials in which the ancient craftsmen had to work. These objects give further evidence of the relatively high culture level of the early immigrants that crossed the strait from Asia.

Mr. JAMES A. FORD, who spent last winter in the Alaskan Arctic, solved the riddle of the ancient mode of Eskimo burial. It has long been thought that the ancient Eskimos at Point Barrow buried their dead either in actual houses or in house-like sepulchres. Mr. FORD discovered that they did neither. They took the top off a natural knoll, laid down a plank floor on which they placed their dead, and then replaced the earth, giving the finished mound a deceptively house-like appearance.

Extra vertebrae in Eskimos.—Supernumerary vertebrae are not uncommon in man; all races show them. But the percentage among Eskimos seems to be high. Among some two hundred Eskimo skeletons examined by Dr. T. D. STEWART at the U. S. National Museum, about twelve per cent had 25 presacral vertebrae, instead of the normal 24. The highest previously reported percentage was 7, among Japanese; Europeans have supernumerary vertebrae in from 3 to 6 per cent of known cases.

Burbank still getting plant patents.—LUTHER BURBANK, though dead, is the holder of more patents under the new plant patent law than any living plant breeder. Recently his seventh plant patent, on a variety of cherry, was granted, through his executrix, ELIZABETH WATERS BURBANK.

Since the passage of the plant patent law a little more than two years ago, 43 patents on plants have been granted.

Corn borer spread retarded.—Due to weather conditions unfavorable for the flight of adult moths, the spread of the European corn borer was retarded during the past season, the U. S. Department of Agriculture has announced. The corn borer area now includes territory as far west as Wisconsin, and extends from the corn-growing provinces of Canada on the north to Kentucky, Virginia, and Maryland on the South.

An ancient "modern" hawk.—At the meeting of the National Academy of Sciences in Ann Arbor, on November 15, Dr. ALEXANDER WETMORE of the U. S. National Museum, with Prof. ERMINE C. CASE of the University of Michigan, presented a paper on the skull of a fossil bird from the Badlands of South Dakota. Although of Oligocene age, the specimen undoubtedly belongs to the living genus *Buteo*.

National Museum has "Uralt" mammal.—A fragmentary skull of a small mammal in the U. S. National Museum has been identified as belonging to the Paleocene genus *Anisonchus* by Dr. GEORGE GAYLORD SIMPSON of the American Museum of Natural History, and is assigned by him to a new species, *A. fortunatus*.

The new species is happily named, for its discovery was apparently a matter of sheer luck. A hollow tool, lowered into a deep oil well in Louisiana, accidentally gouged out a core from the wall, and in this material the broken fossil was found. Thought at first to be Cretaceous in age, its correct date and identity were determined upon more careful examination.

New National Reservations proposed.—Director HORACE M. ALBRIGHT, of the U. S. National Park Service, during his annual summer tour of inspection made a personal investigation of three proposed new national reservations which would be administered by the Park Service. One lies in the Badlands of North Dakota, identified with the name and hunting activities of the late THEODORE ROOSEVELT. A bill sponsored by Senator NYE and Representative SINCLAIR proposes to make this area into a national park. The second proposed new national park would be in the Badlands of South Dakota, along the main road to the Black Hills. This was formerly a great game area, and is still notable for its great wealth of fossils. A third park project is in Wyoming and Nebraska, including Guernsey Lake and historic Fort Laramie. Besides the proposed new national parks, a thorough discussion of the mooted question of the acquisition of lands in the Jackson Hole country, to be offered to the government for park purposes, may be expected during the coming legislative season.

Hybrid Oysters.—Japanese oysters and the oysters of the American Atlantic seaboard are sexually quite compatible, Dr. P. S. GALTSOFF and R. O. SMITH, of the U. S. Bureau of Fisheries, have announced in *Science*. Sperm from the males of either species will induce the females of the other species to discharge their eggs, they found in a series of experiments. Furthermore, viable hybrid oysters are formed, which in the young stages show no higher mortality rate than do "pure-bred" young oysters of either species.

This biological situation does not promise well for the oyster industry of the Atlantic seaboard, fisheries men point out. There is a desire among some of the commercial oystermen to plant the Japanese oyster in Atlantic coast oyster beds. The Japanese species is said to be faster-growing than the

American, but in the opinion of many is of inferior flavor. Champions of the native oyster fear that natural hybridization will ruin the American species. They would like to find legal means to stop the planting of the Japanese oyster, but at present there is no legislation, either state or federal, to help them.

Posters for conservation.—A wild flower poster contest, open to school children in the District of Columbia, as well as to adults, is announced by the Wild Flower Preservation Society. Its purpose is to develop interest in the fate of endangered native species, and at the same time obtain material for use in a campaign of public education. Winners in the District contest, which closes April 15, 1933, will be eligible for a national contest. Particulars may be obtained by addressing The Wild Flower Preservation Society, 3740 Oliver St., Washington, D. C.

News Briefs

Soil scientists from all parts of the United States were in Washington for the meetings of the American Soil Survey Association, November 15 to 17, and the American Society of Agronomy, November 17 and 18.

The Washington section of the Society of American Foresters held its second fall meeting at the Cosmos Club on the evening of November 17. The meeting was addressed by Burt P. Kirkland, of the U. S. Forest Service.

The National Park Service reports the presence in Yellowstone National Park of 58 trumpeter swans during the past season. This bird, though still near extinction, is apparently on the increase in the park area. George Wright, of the National Park Service, is now in Yellowstone studying the winter status of these swans, and also observing the elk on their winter feeding grounds.

The Geological Society of Washington held its 494th meeting at the Cosmos Club on November 9. Dr. T. A. Jaggar, Director of the Hawaiian Volcano Observatory, spoke on *Recent investigations on Pacific volcanology*; Dr. C. S. Ross on *Genesis of titanium deposits of Nelson County, Virginia*, and Mr. W. H. Monroe on *Topography and physiography from aerial photographs.*

The Pan-American Union announces that the White House Conference on Child Welfare held here in 1931 has had a great deal of influence in Latin America. Child Welfare Weeks have been recently held in Venezuela, and in Colombia one was planned, but circumstances compelled its postponement. In Argentina, Dr. Aráoz Alfaro, recognized as dean of his profession, gave a public lecture on the results of the Conference and their possible application to Argentina.

The Washington Chapter of the Pan-American Medical Association held its first winter meeting at the Nicaraguan Legation on November 21.

At the School of Medicine of the George Washington University, a new society named in honor of Theolbald Smith, Walter Reed and Frederick F. Russell, all former professors of bacteriology in the institution, has been formed. The Smith-Reed-Russell Society is sponsoring a series of lectures during the present academic year.

Personal Items

At the meeting of the National Academy of Sciences in Ann Arbor, on November 14, Dr. Walter Hough presented a biographical memoir of the late Dr. Jesse Walter Fewkes.

Dr. W. W. Coblentz was a delegate to the International Light Congress at Copenhagen. He presented a paper on a new standard for ultraviolet light.

Dr. J. A. Fleming has been elected an honorary and corresponding member of the State Russian Geographical Society.

Frank T. Davies, formerly of the Byrd Antarctic Expedition, and now on furlough at the request of the Meteorological Service of Canada, from the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, is in charge of the Polar Year station at Chesterfield Inlet. This station is the nearest point to the North Magnetic Pole at which continuous records will be taken during the Polar Year.

W. J. Rooney, of the Department of Terrestrial Magnetism, who was temporarily assigned to the U. S. Coast and Geodetic Polar Year Station at College, Alaska, to assist in the installation of the atmospheric-electric and earth-current equipment, has completed his work and returned to Washington. K. L. Sherman will be in charge of the work during the Polar Year.

Dr. Luis M. De Bayle, Chargé d'Affaires of Nicaragua in Washington, has been made an honorary member of the Association of Military Surgeons of the United States. His father, a noted surgeon of Nicaragua, was also made an honorary member of the Association of Military Surgeons a few years ago.

Dr. L. O. Howard has returned from his residence in Paris, to resume his research and writing work here. He has a new book in press, which will be published in the near future.

Obituary

Captain Robert Lee Faris, Assistant Director of the U. S. Coast and Geodetic Survey, died suddenly at his home on October 5, 1932. He was born at Caruthersville, Missouri, on January 13, 1868. Graduating from the University of Missouri in 1890, with the degree of Civil Engineer, he served for a year as an assistant engineer with the Corps of Engineers, U. S. Army. He entered the service of the U. S. Coast and Geodetic Survey in 1891. He was engaged upon the various field operations of the Bureau until, in 1906, he became inspector of magnetic work and Chief of the Division of Terrestrial Magnetism, a position he held until 1914, when he became Assistant Inspector of Hydrography and Topography. The following year he was appointed Assistant Director. He wrote widely, contributing many articles and publications relating chiefly to magnetism.

Captain FARIS was appointed a member of the Mississippi River Commission in 1919, and served until his death. He was a fellow of the American Association for the Advancement of Science, a member of the Committee on Navigation and Nautical Instruments of the National Research Council, the Federal Board of Surveys and Maps, the Washington Academy of Sciences, the Philosophical Society of Washington (President 1921), the Washington Society of Engineers (President 1921), the American Society of Civil Engineers, the American Astronomical Society, the American Geophysical Union, the Society of American Military Engineers, the Geological Society of Washington, and of the International Association of Navigation Congresses.

He served as Treasurer of the Washington Academy of Sciences from 1918 to 1930.

BARTON WARREN EVERMANN, director of the Museum of the California Academy of Sciences and of the Steinhart Aquarium, San Francisco, died on September 27, 1932. He was born in Monroe County, Iowa, on October 24, 1853. He matriculated at Butler University, Ind. in 1877. Here he met Dr. David Starr Jordan in whose classes he began the study of natural history. From that day until Doctor Jordan's death in 1931 the two men remained associated in one way or another in their scientific work. Together they made many explorations, collected fish in nearly every state in the Union, and as co-authors they wrote many books and papers. The most important of these is the monumental work in four volumes, *The Fishes of North and Middle America*, published by the U. S. National Museum as Bulletin No. 47 (1896–1900). Another important joint work of Jordan and Evermann is their semipopular book, *American Food and Game Fishes* (1902) which has gone through several editions.

In 1891, Doctor Evermann entered Indiana University, where Doctor Jordan was then professor of biology. Here he received the B.S. degree in 1886, the A.M. in 1888, the Ph.D. in 1891, and the honorary degree of LL.D. in 1928.

In 1891 he joined the staff of the Bureau of Fisheries and in 1902 became Chief of the Division of Statistics and Methods. In 1903 he was appointed Chief of the Division of Scientific Inquiry, and in 1911, Chief of the Alaska Division. He was also curator of fishes in the National Museum from 1905–1914. In 1914 he resigned from the Bureau of Fisheries to become director of the Museum of the California Academy of Sciences, a position he held at the time of his death.

Doctor Evermann served on the U. S. Fur Seal Commission (1892); on the International Fisheries Commission (1908–09); on the Board of Education, Washington, D. C. (1906–10); and lectured at Stanford, Yale, and Cornell. He was a member of many scientific societies and was the author of 387 publications.

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